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TESTING CHANGES IN VISUAL FUNCTION DUE TO ORBITAL ENVIRONMENT

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AIR FORCE AEROSPACE MEDICAL RESEARCH LABORATORY

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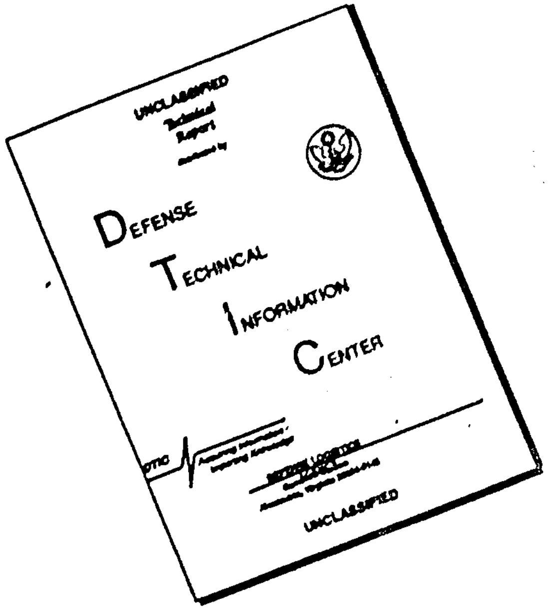

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This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

CHARLES BATES, JR.
Director, Human Engineering Division
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The effects of weightlessness and other space environmental conditions on vision have received little attention since the visual acuity experiments performance by Dr. Duntley, circa 1968. Although several subsequent investigators have attempted to construct vision testers suitable for use in space, none was fully successful until the production of the device described in this report. The report describes a device submitted by the AF Aerospace Medical Research Laboratory for inclusion aboard several NASA Shuttle Flights, in an attempt to detect and quantify certain changes in visual performance caused by the environmental conditions experienced while in earth orbit.

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PREFACE

The device described in this report was designed by H. Lee Task, Ph.D., and Lt Col Louis V. Genco. O.D., as an in-house project for the Air Force Aerospace Medical Research Laboratory, Human Engineering Division, Crew Systems Effectiveness Branch (AFAMRL/HEF). The authors are indebted to several members of Systems Research Laboratories who fabricated the instrumentation, and who assisted in the validation of the various tests, particularly George Dabbs, Sheldon Unger and Martha Hausmann. Capt. Thomas Connon, a USAF optometrist performed the clinical baseline tests described in the text.

We would also like to thank the innumerable individuals who assisted in integrating the visual function tester into the NASA hardware system. Without them, in-orbit testing would have been impossible.

As of the date of this report, the U.S. Air Force is in the process of filing for a U.S. patent on the device, as AF Invention Number 15648, "Portable Vision Function Tester."

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

BACKGROUND

Many of the astronauts have commented on apparent changes in their vision while orbiting the earth. These comments have included statements of supposed "super-vision" by pre-Gemini astronauts, to recent complaints of "presbyopia" and "misplaced horizon" by Space Lab and Shuttle Crew.

Although the literature contains hundreds of references to the supposed effect of orbital environmental conditions on vision, only a few documents describe actual vision tests conducted aboard a spacecraft. Most of these scientifically conducted tests were performed by Dr. S. Q. Duntley and his associates at the Scripps Visibility Lab for NASA's Gemini V and VII, on a very limited number of subjects. There was also a near vision test series sponsored by NASA's Dr. James Vanderploeg performed aboard STS-5 and later flights. This series tested astronaut's accommodative amplitude using a Prince (Krimsky) Rule. STS-8 included a test of an astronaut's contrast sensitivity designed by Maj. Arthur Ginsburg of the Air Force Aerospace Medical Research Laboratory.

The Duntley Tests

The Duntley vision tests were a very ambitious series of ground (preflight), in-cockpit and out the window (during orbit) vision tests. Preliminary plans called for several types of vision tests to be performed, but the actual test series was limited to obtaining baseline and in-orbit measures of the detectability of a 4:1 rectangle under several angular size and two contrast conditions. Essentially, the tests were limited to obtaining only visual acuity measures. Dr. Duntley used a custom designed hand-held instrument to obtain these data, and attempted to validate his findings by out-the-window sightings of ground targets which were also 4:1 rectangles of appropriate visual angles.

Dr. Duntley recommended several types of vision tests be done, in addition to the acuity tests, but they were never performed on subsequent orbital flights. He eventually concluded that vision (i.e. visual acuity) during Gemini flights was relatively unchanged from measures taken on the ground, and the "super-vision" could be explained by ancillary cues and known visibility equations.

RECENT PROBLEMS

Astronauts Carr, Pogue, Slayton and Mattingly have all related the onset of symptoms including a reduction in near visual acuity, with no apparent change in distant vision. Anecdotal evidence also indicated that older astronauts who occasionally wore reading glasses on the ground were more dependent on them while in space. There are indeed symptoms of changes in the astronauts visual system.

AFAMRL INVOLVEMENT

In mid-1982, AFAMRL was invited by Space Division to submit ideas for experiments to be conducted aboard STS-10, the DOD Shuttle originally scheduled to fly in November 1983. A package of three experiments, each designed to complement the other was submitted. This package was the first to address both the astronauts' visual abilities and onboard optical devices as a system rather than unintegrated components. In its original form, the in-cabin portion of the proposal consisted of a series of contrast sensitivity tests which would be mounted on the faceplates of the mid-deck lockers, and a compact state of the art Visual Function Tester which could probe several parameters of "distance" vision. The test system was to be self-contained, draw no power from the Shuttle, and must meet stringent NASA technical, safety and acceptance standards.

This report describes the construction and selection of tests for use in the AFAMRL Visual Function Tester Model 1 (VFT-1). Other publications have and will describe the remaining AFAMRL contributions. This report also contains information comparing the results obtained with VFT-1 to the "standard" Armed Forces vision tester. VFT-1 was approved by NASA to be used aboard STS-14 and subsequent Shuttle missions. A discussion of the data generated using this instrument while on orbit, test results and visual implications will be published in a future report.

VISUAL FUNCTION TESTER MODEL 1 (VFT-1)

Description

The VFT-1 (see Figure 1) was designed to test several parameters of human vision, and indicate the changes in these parameters which may be due to the effects of orbital space flight. The system is self-powered (battery operated), and uses microelectronic circuitry design techniques (see Figure 2) to create a series of controlled illumination stimulus patches at or near optical infinity. Each stimulus patch tests a different visual function. The plans for this device have been submitted for patent application as AF Invention No 15648.

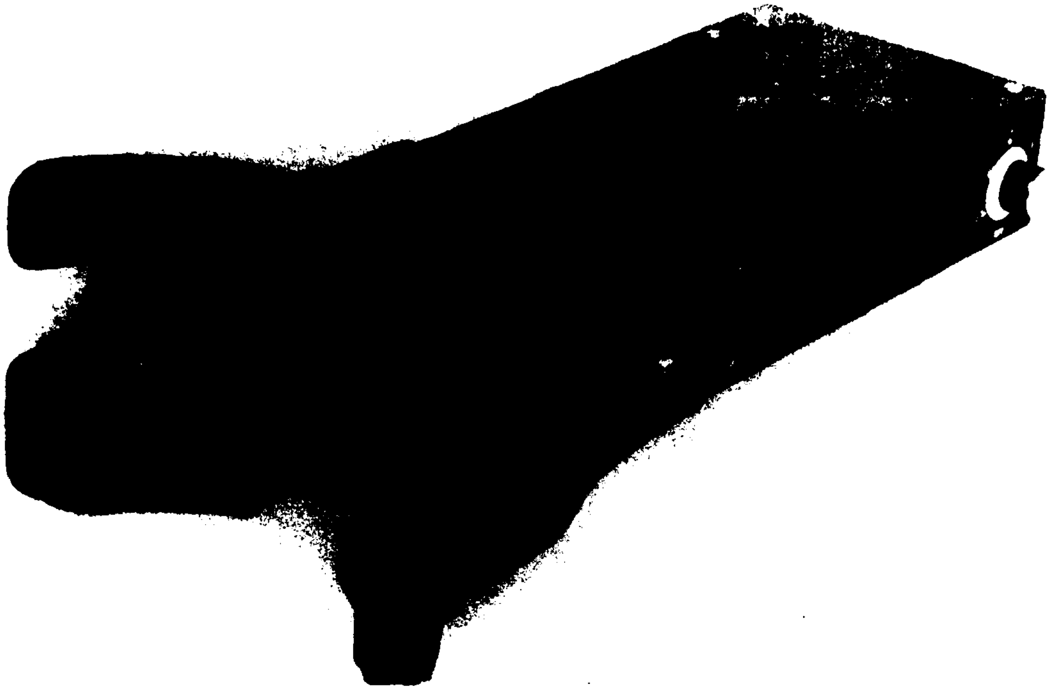


Figure 1
The Visual Function Tester (VFT-1) Top View

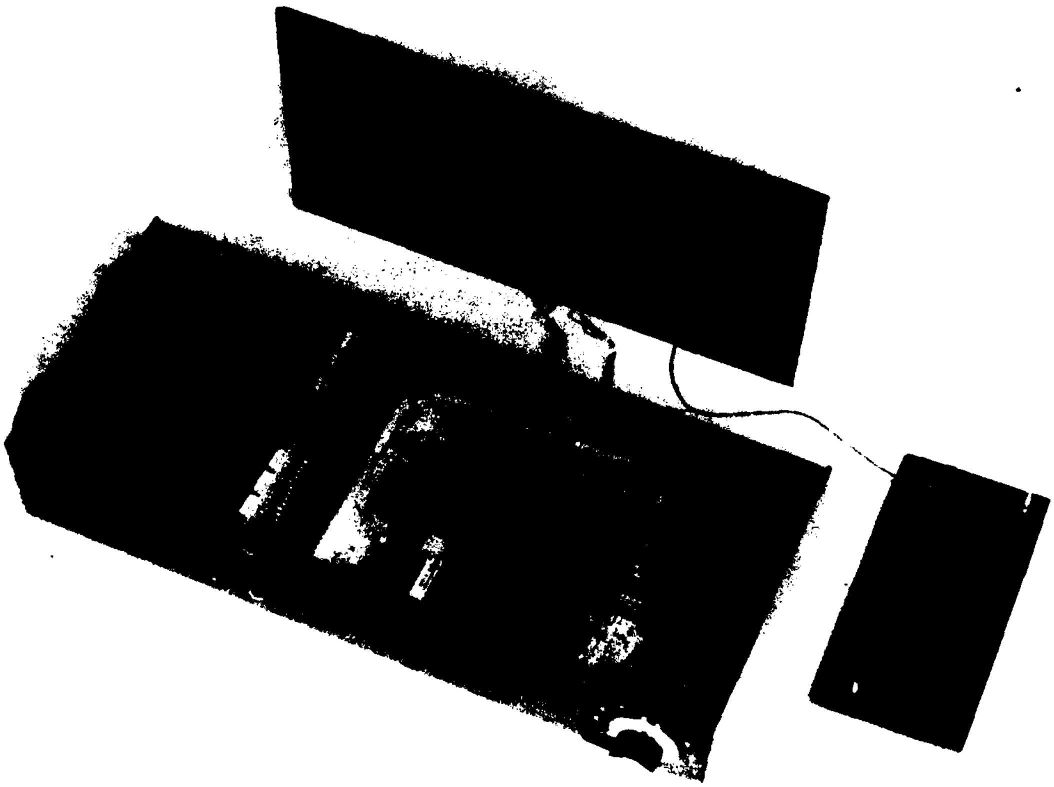


Figure 2
The Visual Function Tester (VFT-1) Inside View

Usage

The subject looks into the device and rotates a multiple position switch located at the right side of the instrument through its various settings (see Figure 3). For two tests, he must press the momentary-contact switches located on the top of the instrument. Data is recorded verbally on a microcassette audio rocorder mounted under the device; the subject reads the test number and the results as shown by the VFT-1. The battery of VFT-1 tests was chosen on the basis of detecting possible changes in neurological or muscular balance caused by microgravity. The rationale and description of each test follow.

Figure 3
Subject Using VFT-1

Critical Fusion Frequency (are the neuronal synapses operating optimally?)

Data is transmitted between our sensory organs, brain and muscles via frequency-encoded nervous transmissions. Whenever a nerve fires, it must "rest" a while before firing again. This resting, or latency period varies, depending on many factors, including physiological state. (see Figure 4) When the electrochemical impulse from one nerve's axone is transmitted to another nerve's dendrite, a chemical change must occur at

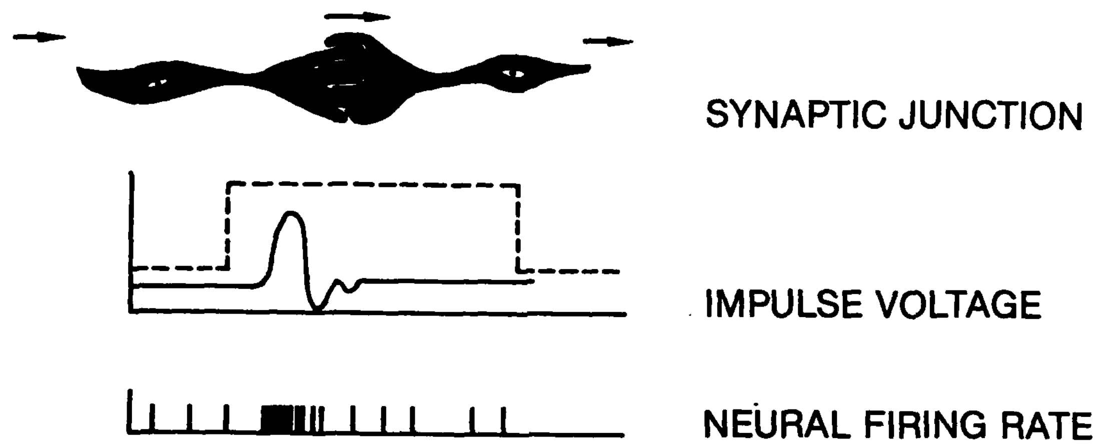


Figure 4
Neural Activity After Sensor Stimulation

the synapse between the nerves. One way to measure the nerves' ability to conduct signals is to input a known signal at a sense organ, and test the brain's ability to detect the signal.

A simple example is Critical Fusion Frequency (CFF) or Flicker Fusion Frequency (FFF). A blinking light is presented to the eyes, and the blink frequency is increased until the light fuses or appears steady and unblinking. This critical fusion frequency is an indication of the physiological state of the nervous system. If CFF changes, nervous transmission speed may have been affected due to fatigue or other physiological changes occurring at the synapses, thus affecting our ability to properly gather and analyze sensory data. "Normal" CFF is between 50 Hz and 70 Hz, depending on several factors, including the portion of the retina which is stimulated.

The CFF test stimulus in VFT-1 is a circular patch (approximately 5 degrees in diameter.) which is retro-illuminated by a "yellow" flat LED. The LED is wired to emit a square-wave blink whose frequency is controlled by the microelectronics in VFT-1. The subject looks into the device and presses the UP (right) button until the flickering light is seen as steady. He then looks outside the device at a seven-segment display mounted on the top of the device, and presses the FREQ button. The number indicated on the display is the CFF in Hertz. The subject verbally records this value, then presses the DOWN button to lower the frequency past his threshold.

This test (Foveal Flicker Fusion Frequency) is repeated several times, after which the subject looks at a fixation dot located several degrees to the right of the CFF patch, and repeats the test several more times. This latter test measures the Peripheral Flicker Fusion Frequency. Since the vasculature of the peripheral retina is markedly different from that of the macular area, earlier changes may occur in the peripheral field of view.

Stereopsis (clinical depth perception) and Suppression.

Although there are at least six visual cues to depth perception, many of them are absent in the textureless visual environment encountered when looking outside a spacecraft. Stereopsis (a function of retinal) disparity) may then be of increased importance to the safety and control of docking, untethered maneuvers and other nearby operations. Stereopsis requires fine fusional control and a high level of cerebral interpretation of visual data. Under laboratory conditions, some people have displayed stereoacuity as fine as two seconds of arc. These individuals are able to see a difference in depth between similar objects placed at "infinity" and at 3350 meters.

We test stereopsis to see if there is any decrement in this visual parameter due to capsule environmental conditions or physiological changes in the crew. This test is similar to that taken on aircrew flying physicals. Four dots are seen in each of several test patches. (See Figure 5) The subject identifies which test patch he is observing, and which dot is closer than the others. Because of optical limitations in the device, and the probability that under field conditions maximal stereocuity will not be attained, we test only to about ten seconds of arc.

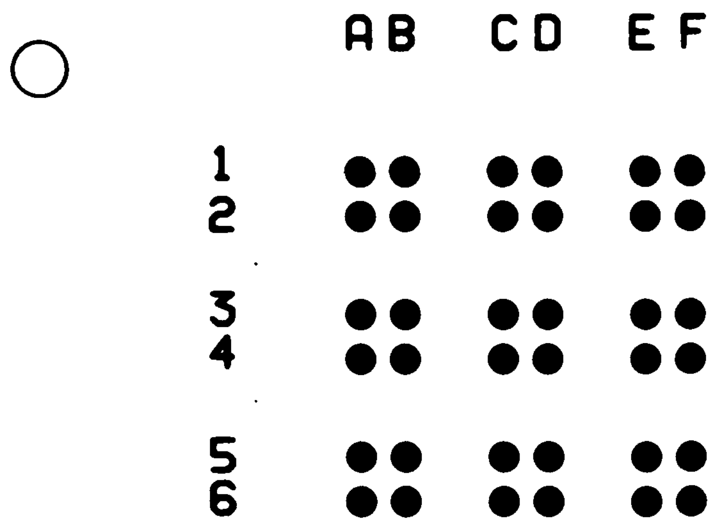


Figure 5.
Stereopsis Target

One reason for degraded stereopsis is suppression, or the circle (seen by both eyes) with a diagonal line seen by each eye. If the subject sees either a (\) or a (/), he is suppressing one eye; if he sees an "X" both eyes are working together.

<u>Snellen Acuity</u> (what is the smallest letter one can read? How far away can one read letters?)

Typically, the retinal image is degraded by both the environmental conditions and the media of the eye. The retinal image of a point source is not a point, but approximates a Gaussian distribution of energy.

The left part of the acuity test patch (See Figure 6) contains four rectangles, identified by coordinates numbered from 1 through 8, and lettered from A through D. The subject is to indicate the orientation of the Snellen Es within each rectangle. This test indicates the smallest (farthest) resolvable letter of multiple spatial frequency content.

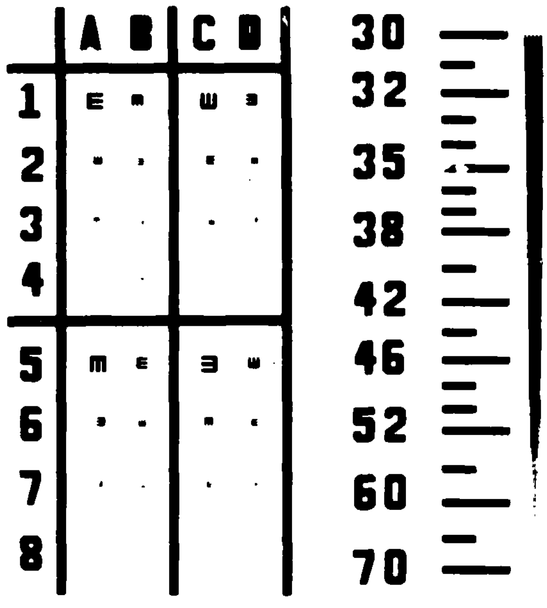


Figure 6.
High-Contrast, High-Resolution Acuity Target

Minimum Resolution Acuity (what is the smallest separation or detail one can see?)

Ability to identify (read) letters probably occupies the highest place in the heirarchy of visual functions. Simple detection occupies the lowest. Once a target is detected, it is important to determine whether the target is one or more than one; or if there exists important detail or textural information.

The right part of the test patch (See Figure 6) contains a RETMA fan. At the left of the fan is a series of numbers and pointer lines. The subject is to indicate the number corresponding to the level at which the distinct RETMA fan lines blur or merge into one. This number represents the spatial frequency of the fan in cycles per degree, at the point indicated.

Mesopic Visual Acuity Test (how well can one see in dim light?) or Medium Contrast/backup acuity (resolution) test (see Figures 7 and 8).

Because of the absence of atmosphere and other light-scattering particulates in space, objects seen against the starry background will always be of high contrast. The addition of tinted visors and other transparent materials will reduce the transmitted light energy, but may not affect contrast (unless dirty or of poor quality). Lowering the overall light level impingent on the retina will cause the visual system to shift from photopic through mesopic to scotopic vision. The effects of reduced contrast or transmission on astronauts' visual performance have yet to be studied.

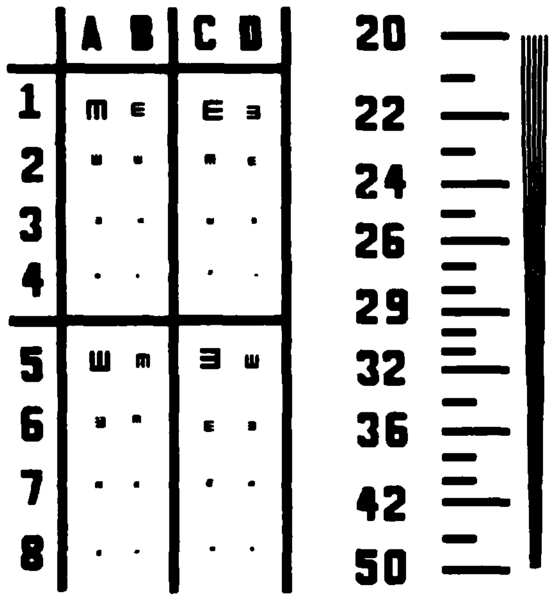


Figure 7
Backup Acuity Test

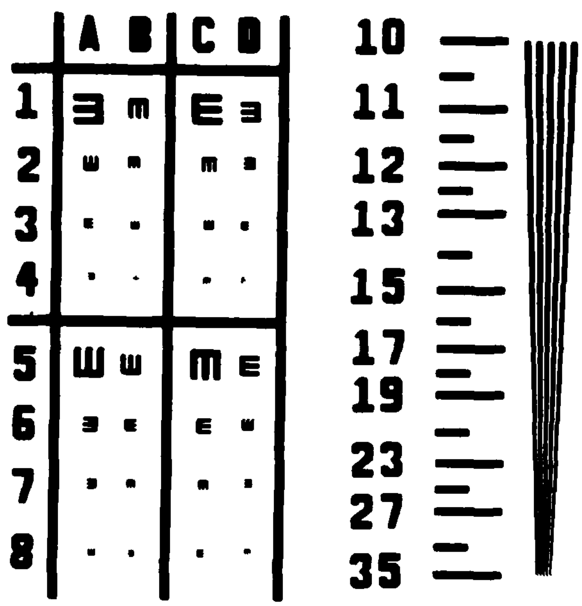


Figure 8
Backup Acuity Test

These two targets in VFT-1 were considered for fitting with appropriate neutral density filters to provide luminances in the mesopic range. In the final version, the filters were not used, so the two targets provide alternate or backup visual acuity tests in the photopic range.

Cyclophoria (describes the relative position of the eyes along the Z-axis.)

Normally, tilting one's head to the right or left will result in the eyes torquing slightly in the opposite direction in an attempt to compensate and keep the retinal image of the horizon horizontal. There is evidence indicating head tilt (as detected by the simicircular canals of the ear) is partially compensated in our visual system by activity of the oblique muscles of the eyes. This linkage may contribute to a better perception of one's position in space with respect to the horizon. In space, gravity does not provide cues for "true" vertical, and the semicircular canals are relatively useless. In addition, the otolith mechanism is rendered ineffectual by a combination of weightlessness and decalcification of the tiny otoliths themselves. Interference with these linkages appears to contribute to symptoms of vertigo.

Figure 9 shows the Torsional Phoria stimulus patch as seen by the left eye, and Figure 10 shows the patch as seen by the right eye. The circles serve to help fuse the targets for vertical and horizontal displacements, while allowing free torsional movements. There is no fusion stimulus for torsion. The subject identifies at which number the arrow points. Each tic mark represents one degree of rotation. If the eyes have not rotated, the subject will report the arrow pointing to the number 45 (or 4.5).

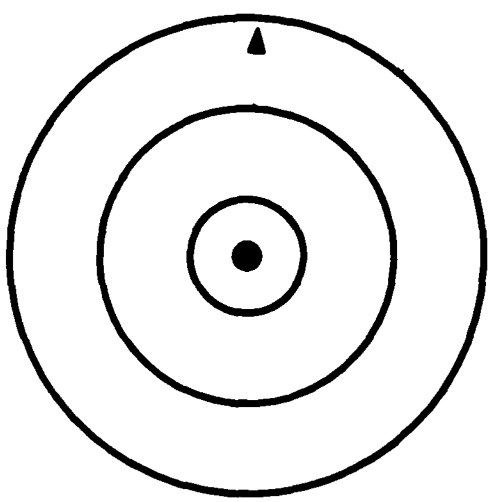


Figure 9
Torsional Phoria Target

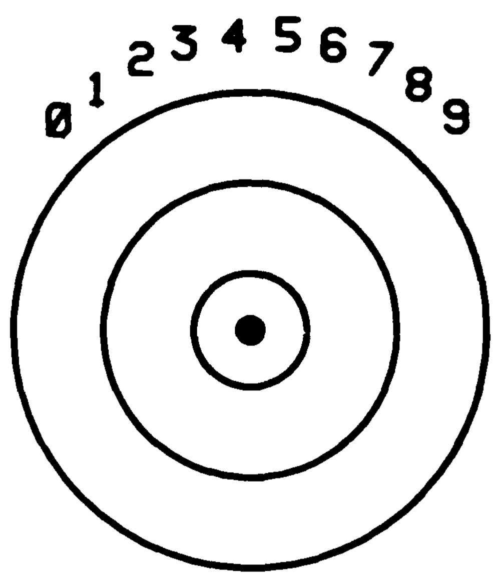


Figure 10
Torsional Phoria Target

Retinal Rivalry (is one eye or one cerebral hemisphere more dominant than the other?)

The use of Heads-Up Displays (HUDs) and Helmet-Mounted Displays (HMDs) has sensitized us to the importance of binocular vision. If Single Simultaneous Binocular Vision is degraded by weightlessness or other conditions, certain haploptically presented visual displays will also be affected. If imagery is presented only to one eye, and different visual information to the other, retinal rivalry will cause only portions of each image to be "seen" at any one time. Typically, the perceived scene shifts back and forth, depending on which eye (or field of view) is "dominant" for that moment. One way to test retinal rivalry is to measure the rate at which the eyes trade dominancy, and the duration for which each eye is dominant.

This test presents a different colored/patterned image to each eye. (See Figures 11 and 12). With both eyes open, and while observing the target for approximately half a minute, the subject is to continually report which pattern occupies most of his field of view.

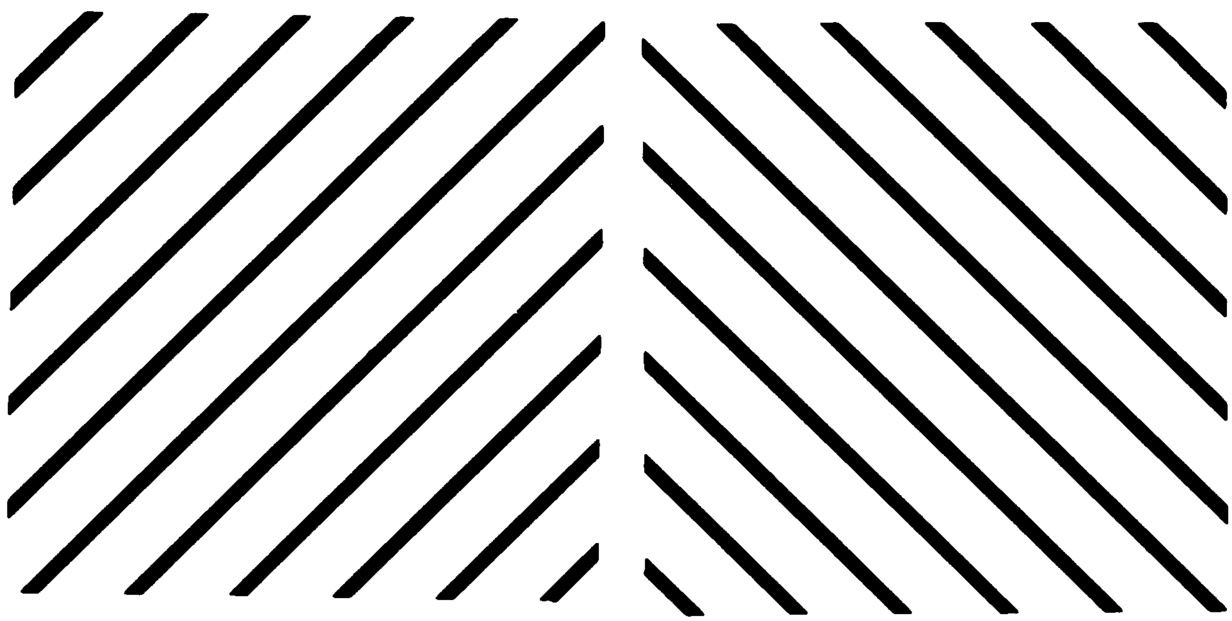


Figure 11
Retinal Rivalry Target, Left Eye

Figure 12
Retinal Rivalry Target, Right Eye

Lateral and Vertical Heterophorias (describe the relative position of the eyes along the X and Y axes.)

Normally, the lines of sight (imaginary lines extending from the fovea of each eye) intersect at the object of regard. When extremely stressed or fatigued, or under the influence of drugs or alcohol, or when dissociated for some other reason, our eyes' lines of sight move toward a "position of rest." For most people, this latter position is dissimilar from that assumed when in a normally alert state. If a person's lines of sight no longer intersect the point of regard when one eye's vision is dissociated from the other, that person is said to have a "heterophoria". In individuals with high heterophorias, the visual system has to work harder to prevent double vision. On Earth, heterophorias usually remain fairly constant over short (day to day) periods. We have little information on the favored position of the eyes while in space.

Some individuals' lines of sight are such that both eyes are not aligned with the object of regard. These individuals are said to have heterotropias. VFT-1 has one test specifically designed to detect and measure the magnitude and direction of both vertical and horizontal (lateral) heterotropias or heterophorias.

The stimulus for the left eye is initially invisible. When evoked, the left eye sees a short-duration flash of a small dot (see Figure 13). The stimulus for the right eye consists of a lettered and numbered matrix of squares (see Figure 14). The subject identifies in which square the bright dot is located. Each square represents 10 milliradians, or 1 prism diopter. If the flash occurred too fast to note the position of the dot, the subject can press the FREQ button to repeat the test.

Figure 13
Heterophoria/Tropia Target (Left Eye)

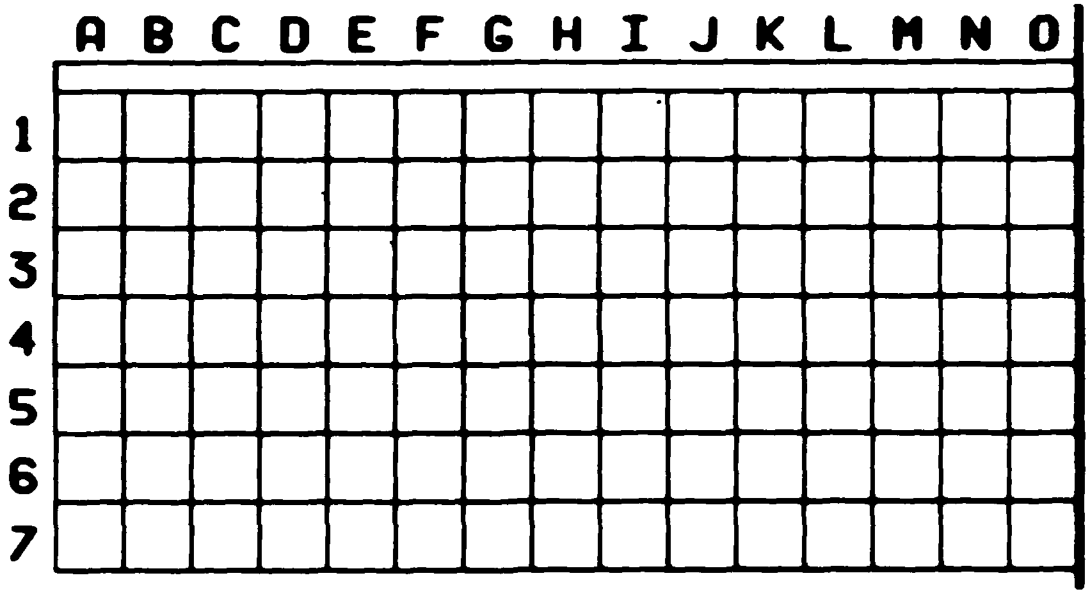


Figure 14
Heterophoria/Tropia Target (Right Eye)

PROPOSED ADDITIONAL TESTS FOR VFT-n (Follow-on studies.)

As with any physiological test, we expect to see some variability from individual to individual. For example, accommodative ability is significantly affected by age. Vision tests similar to those mentioned above should be performed on a large number of people experiencing weightlessness for various periods of time to determine if this or associated parameters truly affect visual performance.

While constructing VFT-1, several additional tests were suggested, but not implemented because of time constraints. The following is a partial

listing of additional vision tests which could be implemented in subsequent versions of the Visual Function Tester. As of the date of drafting this report, VFT-2 is under construction and VFT-3 is being designed.

1. Accommodation

Accommodation, or focusing is accomplished by changing the tension on a series of tiny muscles attached to each eye lens. If the muscles react differently due to absence of gravity, or if the lens position is slightly changed from that experienced on Earth, retinal image clarity may be affected.

VFT-3 will be able to test both amplitude and speed of accommodation, for various targets.

2. Contrast Threshold

The eye does not just detect sharp edges, but detects the contrast ratio between adjoining areas. If this contrast ratio is sufficiently low, no difference will be seen between adjoining test patches; in other words, a very low contrast target is invisible against the background. The threshold at which the eye can discriminate among low-contrast targets will be measured.

VFT-2 will have variable contrast ratio targets of several types: Gratings, resolution fans, "Blackwell Disks", and others. Since the retinal image of a point source of light is not a point but a Gaussian distribution of energy, use of Gaussian targets can be helpful in predicting visual performance on both letter type targets (as in clinical visual acuity tests) and real-world targets experienced in daily visual tasks.

3. Intraocular Pressure

There is a constant production of aqueous humor in each eye. This fluid helps to maintain the shape of the eye. The fluid is drained via tiny canals located at the base of the iris, and (according to some authors) via the iris itself. Excess production or insufficient drainage of the fluid will increase the intraocular pressure (IOP) and decrease the ability of the choroidal and retinal vascular systems to nourish the eye. On earth, this condition is called Glaucoma. Long-term elevated IOP eventually leads to blindness.

A separate device can be constructed, independent of weight-loaded tonometer principles. A modified "air-puff" tonometer is being considered. Applanation types can also be studied, but (because of the requirement for corneal anesthesia) will probably not be used.

SUMMARY

Baseline and follow on Visual Function test values were compared to validate test and retest data. In all cases, this comparison indicated an extremely close compatibility of the data, assuring that differences in measurements are due to changes in the visual function being measured rather than in the instrument. The mean and standard deviation of the "individual test" phorias would have been even "tighter" if one subject were excluded. During cyclophoria testing, this individual varied 10 prism diopters between two test dates, compared to a second highest value of only one prism diopter. Another subject varied 32 Hz across peripheral flicker measurements. Follow on tests with different eye instruments verified that this was due to subject variability rather than test instrument error.

Comparison studies between VFT-1 and the DOD "standard" visual screening instrument indicated VFT-1 correlations were generally much higher than those obtained with the AFVTA-ND. Since the two instruments did not refine data to the same "bin sizes", cross-correlations were unsatisfactory.

Limited data taken with a phoropter operated by an USAF optometrist were also compared to similar tests taken with VFT-1. For those clinical tests which could be compared with the VFT-1 battery, very favorable relationships could be established indicating a close approximation between values. Some variability in absolute phoria values (increased eso while being tested with VFT-1) is expected because of the "proximity effect" induced by any relatively small hand-held instrument. This proximity effect explains many of the differences between visual performance in an unconstrained environment and that in a restricted test apparatus. (The "proximity effect" or "proximal convergence effect" is an apparent increase in myopia and/or esophoria when these parameters are measured with enclosed instruments).

CONCLUSION

The VFT-1 was shown to be a highly valid method for testing changes in certain parameters of visual performance. Relative values for baseline and follow on tests will indicate excellent sensitivity for small changes in CFF, resolution acuity, muscle balance and stereopsis. Correlation with clinical testing is good, with most differences being attributable to the differences in accommodative and fixation patterns differences experienced when comparing an enclosed instrument to a 20-foot test lane. Correlation with clinical screening instruments is only fair, but this was due to the variability within the clinical screening instruments rather than the VFT-1.

APPENDIX A

Validation Studies

Since the Visual Function Tester (VFT-1) is a newly devised instrument, a series of studies were conducted to validate the data acquired with the device, and compare results with the "standard" DOD eye test. One study compared two versions of VFT-1; one with a standard test plate, the other with a modified (high optical density) test plate. Another study compared two Armed Forces Vision Test Apparatus, Near and Distant (AFVTA-ND) devices; one "fresh from the box" and the other several years old (used in one of the WPAFB clinics). Finally, the results of VFT-1 tests were compared to the results of the AFVTA-ND tests.

VFT-1A -vs- VFT-1B

Two VFT-1 devices were used, one having a higher density optical plate than the other. This condition was taken as "worst case", since repeat measurements taken with the same instrument should tend to show less variability. Fifteen subjects (nine males and six females) ranging in age from 19 years to 31 years (mean age = 21.8 years) participated in this comparison/repeatability study. Each subject was tested on VFT-1A, and VFT-1B for 12 days. The order of testing on each of the VFT-1 devices was alternated for each subject each test day.

Although the VFT-1 devices are designed for battery power, for economy and insurance of a constant voltage, an AC battery eliminator was used during early test phases. After noting what appeared to be an extremely high CFF on most subjects, the power supply was found to be causing a beat frequency with the CFF oscillator. The result was a visible flicker even at extremely high settings. All CFF data were then retaken using appropriate batteries, and periodically checking for low charge. One subject still showed a very high CFF, while one showed a very low CFF. These subjects and their responses are being studied in a separate effort.

The means of all individual test data were concatenated to show group results for a particular test. The following tables show the results of statistical reduction.

TABLE 1.
Comparison of VFT-1A and VFT-1B Results

TEST NAME		VFT-1A	VFT-1B	
CFF (Central)	Mean of Means	60.037	60.205	(Hz)
	S.D. of Means	10.447	10.400	
	Mean of S.D.s	2.852	3.05	
	S.D. of S.D.s	1.187	1.86	
	Mean High	89.50	88.24	
	Mean Low	40.73	40.02	
	r = 0.996	Coefficient of Correlation		
	m = 0.992	Slope		
	b = 0.660	Y-intercept		
(Peripheral)	Mean of Means	64.262	63.791	(Hz)
	S.D. of Means	16.479	17.513	
	Mean of S.D.s	4.307	4.549	
	S.D. of S.D.s	1.336	2.179	
	Mean High	93.02	94.09	
	Mean Low	35.20	34.98	
	r = 0.995	m = 1.058	b =-4.225	
Visual Acuity (E)	Mean of Means	0.61	0.577	(Arc-min)
	S.D. of Means	0.045	0.057	
	Mean of S.D.s	0.04	0.39	
	S.D. of S.D.s	0.016	0.013	
	% Difference of Means*		5.875%	
	% Difference of S.D.s		4.205%	
	r = 0.933	m = 1.197	b = -0.154	
Stereopsis	Mean of Means	12.85	14.97	(Arc-sec)
	S.D. of Means	3.574	5.969	
	Mean of S.D.s	4.40	4.39	
	S.D. of S.D.s	4.991	3.628	
	% Difference of Means		-12.175%	
	% Difference of S.D.s		19.397%	
	r = 0.894	m = 1.493	b = -4.157	

TABLE 1 (Continued)

RETMA Fan	Mean of Means	49.48	48.85	(Cycles/degree)
	S.D. of Means	6.013	5.947	
	Mean of S.D.s	2.77	2.87	
	S.D. of S.D.s	1.664	1.802	
	Difference of Means**		0.635	
	Difference of S.D.s		0.662	
	r = 0.994	m = 0.983	b = 0.209	
Cyclo-Phoria	Mean of Means	-0.16	-0.10	(Prism diopter)
	S.D. of Means	0.345	0.314	
	Mean of S.D.s	0.09	0.09	
	S.D. of S.D.s	0.072	0.117	
	Difference of Means		-0.053	
	Difference of S.D.s		0.055	
	r = 0.99	m = 0.904	b = 0.038	
Lateral Phoria	Mean of Means	1.3	1.1	(Prism diopter)
	S.D. of Means	1.466	1.465	
	Mean of S.D.s	0.45	0.48	
	S.D. of S.D.s	0.219	0.161	
	Difference of Means		0.199	
	Difference of S.D.s		0.158	
	r = 0.994	m = 0.994	b = -0.191	
Vertical Phoria	Mean of Means	0.08	0.1	(Prism diopter)
	S.D. of Means	0.468	0.481	
	Mean of S.D.s	0.14	0.15	
	S.D. of S.D.s	0.118	0.156	
	Difference of Means		-0.02	
	Difference of S.D.s		0.077	
	r = 0.987	m = 1.016	b = 0.019	

* % Difference = $\frac{A-B}{x_{A,B}}$

** Difference = A - B

AFVTA-ND1 -vs- AFVTA-ND2

Eighty-eight subjects (21 females and 67 males) between the ages of 20 and 50+ were tested, using standard clinical techniques, on two AFVTA-ND devices of different ages (VTA-ND1 was new, while VTA-ND2 was at least 10 years old), with the following results:

TABLE 2
Comparison of VTA-ND1 with VTA-ND2 Results

Test Name	VTA-ND1	VTA-ND2
Visual Acuity (OD)		
Mean (arc-minutes)	19.080	19.318
Standard Deviation	5.527	6.965
Correlation Coeff.	0.811	
Visual Acuity (OS)		
Mean (arc-minutes)	18.080	18.386
Standard Deviation	3.862	4.752
Correlation Coeff.	0.750	
Stereopsis (n = 77 and 79, since some subjects had no stereopsis)		
Mean (arc-seconds)	16.234	16.392
Standard Deviation	4.425	4.098
Correlation Coeff.	0.755	
Lateral Phoria (n = 87, one subject off-scale)		
Mean (prism diopters)	0.054	1.443
Standard Deviation	7.369	3.858
Correlation Coeff.	0.607	
Vertical Phoria		
Mean (prism diopters)	0.032	0.132
Standard Deviation	0.330	0.343
Correlation Coeff.	0.666	

VFT-1 -vs- AFVTA-ND

The VFT-1 devices tested Critical Flicker Frequency, Stereopsis, Binocular Visual Acuity, Spatial Frequency, Eye Dominance, Cyclophoria, Lateral Phoria and Vertical Phoria. The AFVTA-ND tested Monocular Visual Acuity, Stereopsis, Lateral and Vertical Phorias. One subject's data were removed from the lateral and vertical phoria tests since his values exceeded the measurement range of the instruments.

Although both instruments measured several visual parameters in common, the stimulus value and step sizes differed between the AFVTA-ND and the VFT-1. The AFVTA-ND Stereopsis stimuli were presented in the following steps (in seconds of arc): 80, 40, 30, 25, 20, 15. The VFT-1 presented the stereopsis stimuli in the following series (also seconds of arc): 80, 70, 60, 50, 40, 30, 22, 16, 10. Visual Acuity stimuli on the AFVTA-ND were in the following steps: 20/50, 20/40, 20/30, 20/25, 20/20, 20/17.5, 20/15, 20/12.5. Similar stimuli on the VFT-1 were as follows: 20/60, 20/40, 20/39.5, 20/31, 20/29.4, 20/26.9, 20/22, 20/23.4, 20/20.3, 20/19.5, 20/16.7, 20/16.3, 20/14.6, 20/13.6, 20/12.9, 20/11.7, 20/11.4, 20/10.2, 20/9.8, 20/9.1, 20/8.6, and 20/7.7

Several parametric methods were applied to describe the data, including the Cohen K, but none were successful in establishing a rigorous correlation. This was due to different measurement step functions as described above. Because of the dissimilarities between the two instruments (VTA-ND and VFT-1), strict parametric comparisons were difficult to obtain. In addition, since the norm for the phoria tests was Zero, any departure from the norm would appear to be excessive. Another problem was the discrete distribution of the data; the data clumped about a limited number of stepwise values, and were not continuous in nature.

Since each device was constructed using approved optical engineering principles, and should proffer constant stimuli, a study was undertaken to define the variability of data obtained with each instrument under normal operating conditions. Determination of the subject variability for a relatively large n would then indicate what magnitude of changes might be expected to be important when the device was used in Space, as well as indicate which instrument had better repeatability.

The following table shows correlation coefficients derived when comparing the VFT-1 results to the AFVTA-ND results.

TABLE 3
Correlation Coefficients - VFT-1 and AFVTA-ND

TEST		AFVTA-NDs	VFT-1s
CFF			
Foveal		n/a	0.996
Peripheral		n/a	0.995
Visual Acuity			
Binocular		n/a	0.933
Monocular	(right eye)	0.81	n/a
	(left eye)	0.75	n/a
Stereopsis		0.755	0.894
RETMA Fan		n/a	0.994
Cyclophoria		n/a	0.99
Lateral Phoria		0.607	0.994
Vertical Phoria		0.666	0.987

In all cases, the VFT-1 showed better correlations than did the AFVTA-ND. This validated the use of two VFT-1 devices - one for pre- and post orbit tests, and one for in-orbit tests. In addition to the possibility of better optical quality in the VFT-1s, some of the difference in correlation coefficients may be due to a learning function during the 12 VFT-1 test days, even though "correct answers" were different in each instrument. Also, the AFVTA-ND was developed as a "screening instrument" to determine whether examinees need further testing at the Eye Clinic. As such, it was conservatively designed to overrefer examinees.

APPENDIX B

VFT-1 Parts List

Integrated Circuits		Quantity
MC14516B	.'otorola	8
MC14553B	"	3
MC14543B	"	1
MC14013B	"	1
MC14490	"	1
MM74C00N	National Semiconductor	3
MM74C02N	" "	3
MC74C04N	" "	1
MM74C14N	" "	1
9667DC	Fairchild Transistor Array	1

Diodes

1N914		10
1N4002		2

Capacitors

UK25-103	Centralab .01UFD Ceramic Disc (Y5P)	18
196D395X90125HA1	Sprague 3.9UFD 15V.	2
	200PF	2

Resistors

	160 OHM Y2 Watt Carbon	1
	51 KOHM Y4 Watt Carbon	4
	680 OHM Y4 Watt Carbon	1
	30 OHM Y4 Watt Carbon	2
	2 KOHM Y4 Watt Carbon	1
	62 KOHM Y4 Watt Carbon	1
16-1-102	Bourns Resistor Network	1

Displays

5082-7433 H-P	3 Digit Display	1
HLMP-2855 H-P	LED Light Bar Modules	13
HLMP-2500 H-P	" " " "	4
HLMP-2885 H-P	" " " "	2
HLMP-2655 H-P	" " " "	1

Oscillator

MCO-TI-SO	M-Tron 1MHZ	1

Switches

8121-J83-Z	C&K Pushbutton	3
81073	Grayhill Rotary	1

Flex Strips

FST-2-A-12	Ansley	2

Battery & Accessories

270-325	Radio Shack Battery Clip	1
270-384	Radio Shack Battery Holder	1
E91	Eveready Alkaline Energizer	6

PC Boards

SRL 5007-0608009		1
CCI - I-O	LED Light Bar Module Board	1

Sockets

C931402	T.I. 14 Pin Sockets	10
C931602	T.I. 16 Pin Sockets	15
14-8-125-10	Aries 14PIN High Rise Socket	1

Bezel

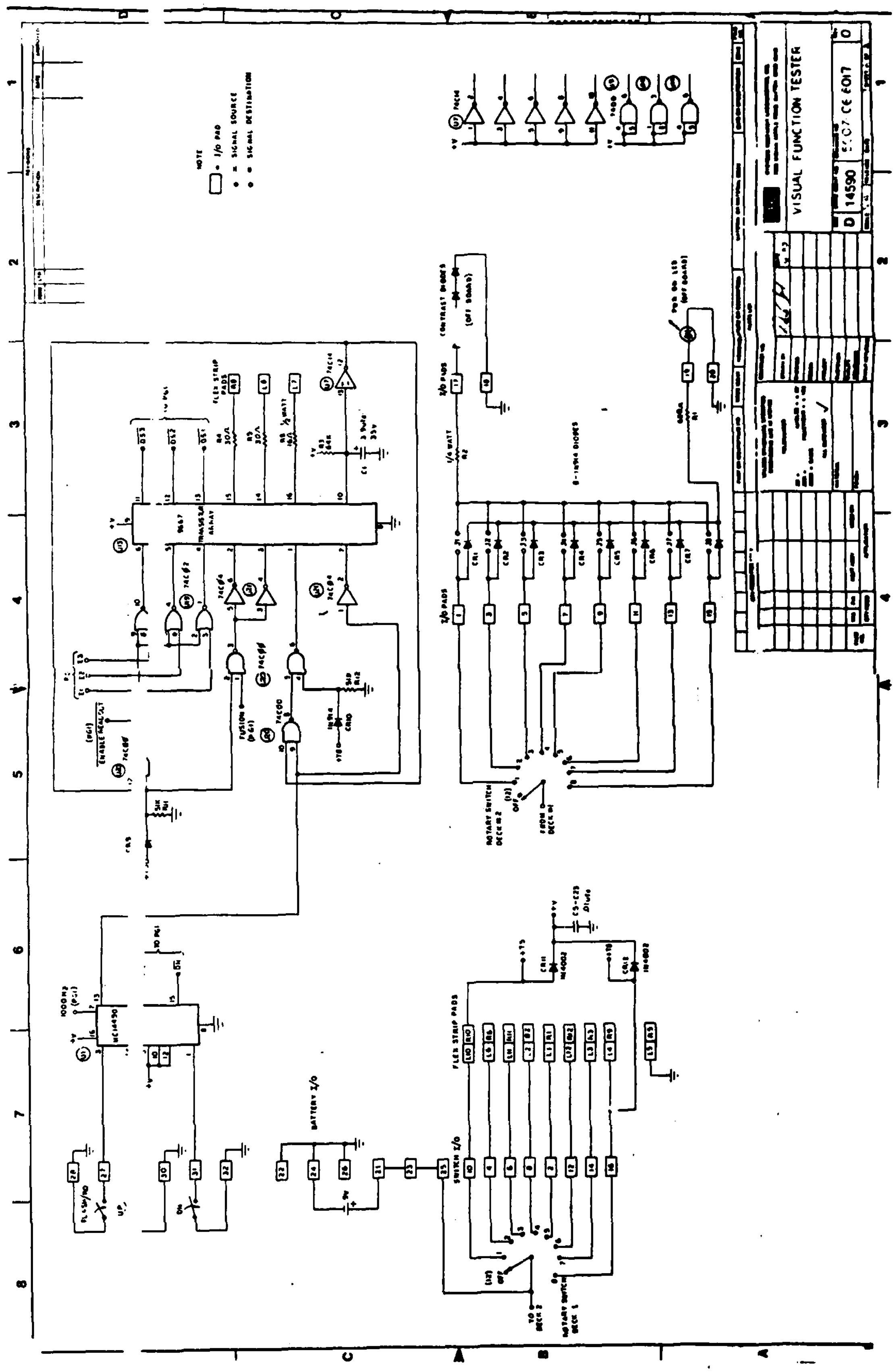
DMH22463M-02	I.E.E. Display Bevel	1

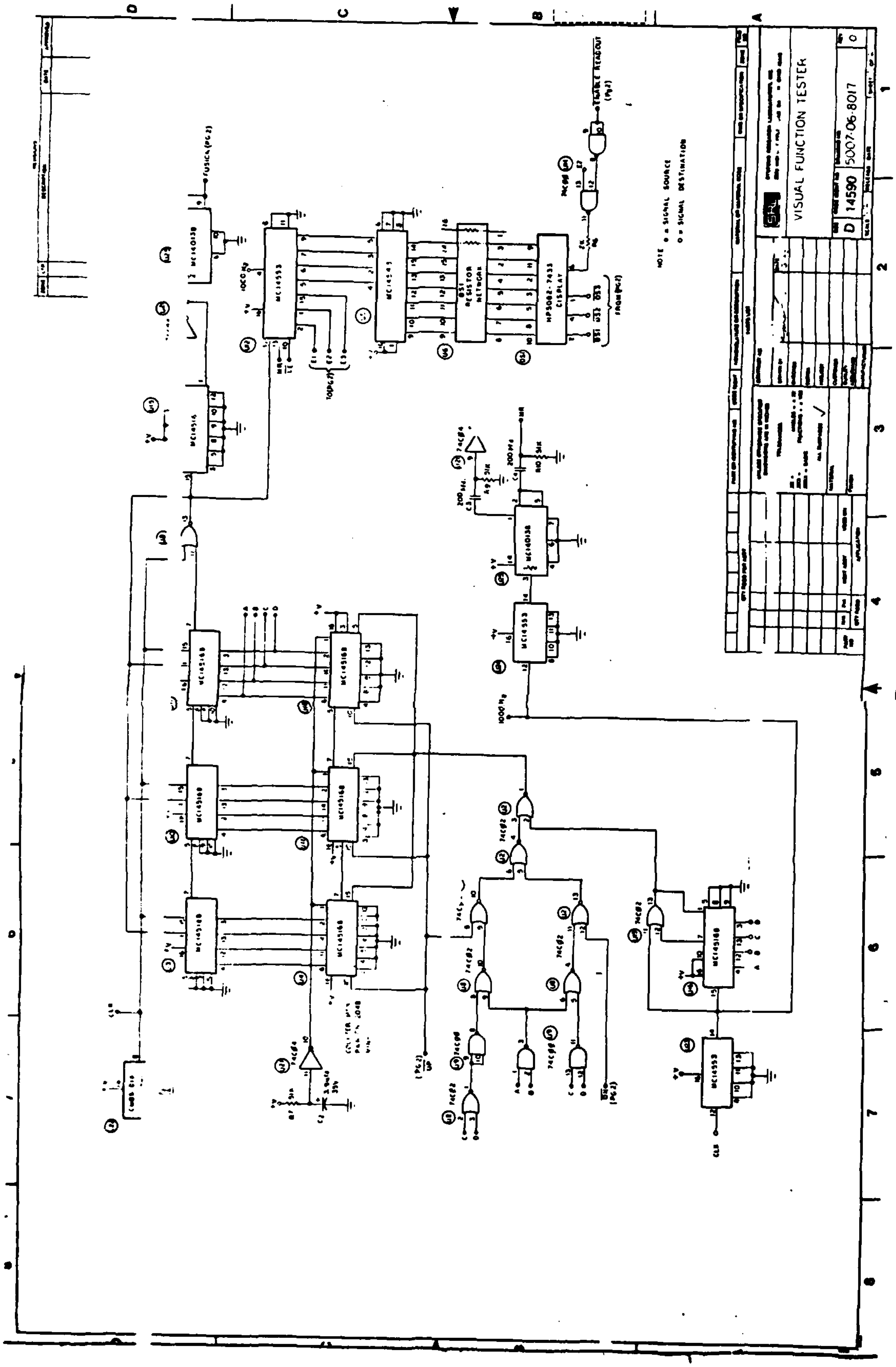
Led

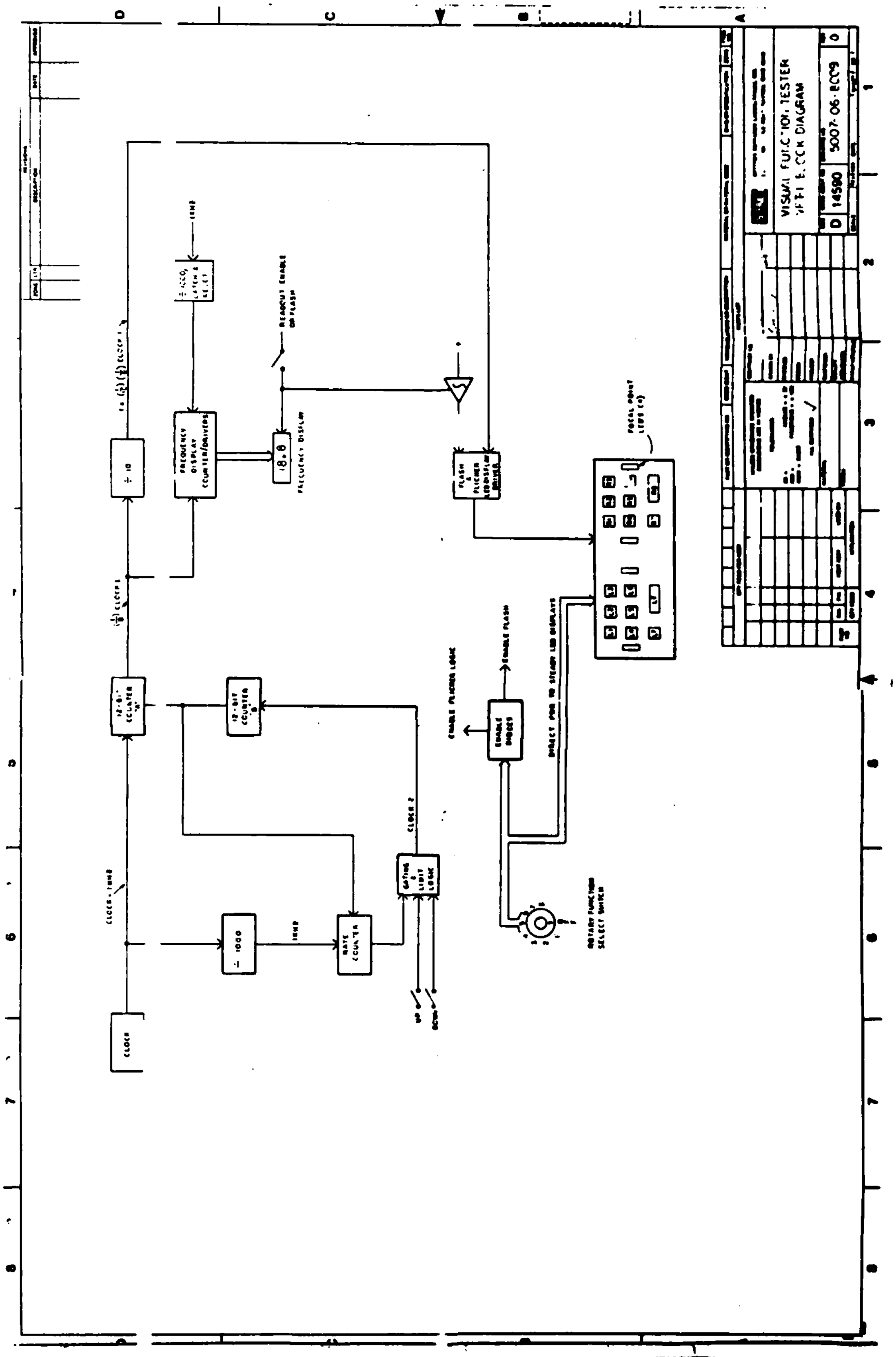
558-0201-003	Pialight Led	1

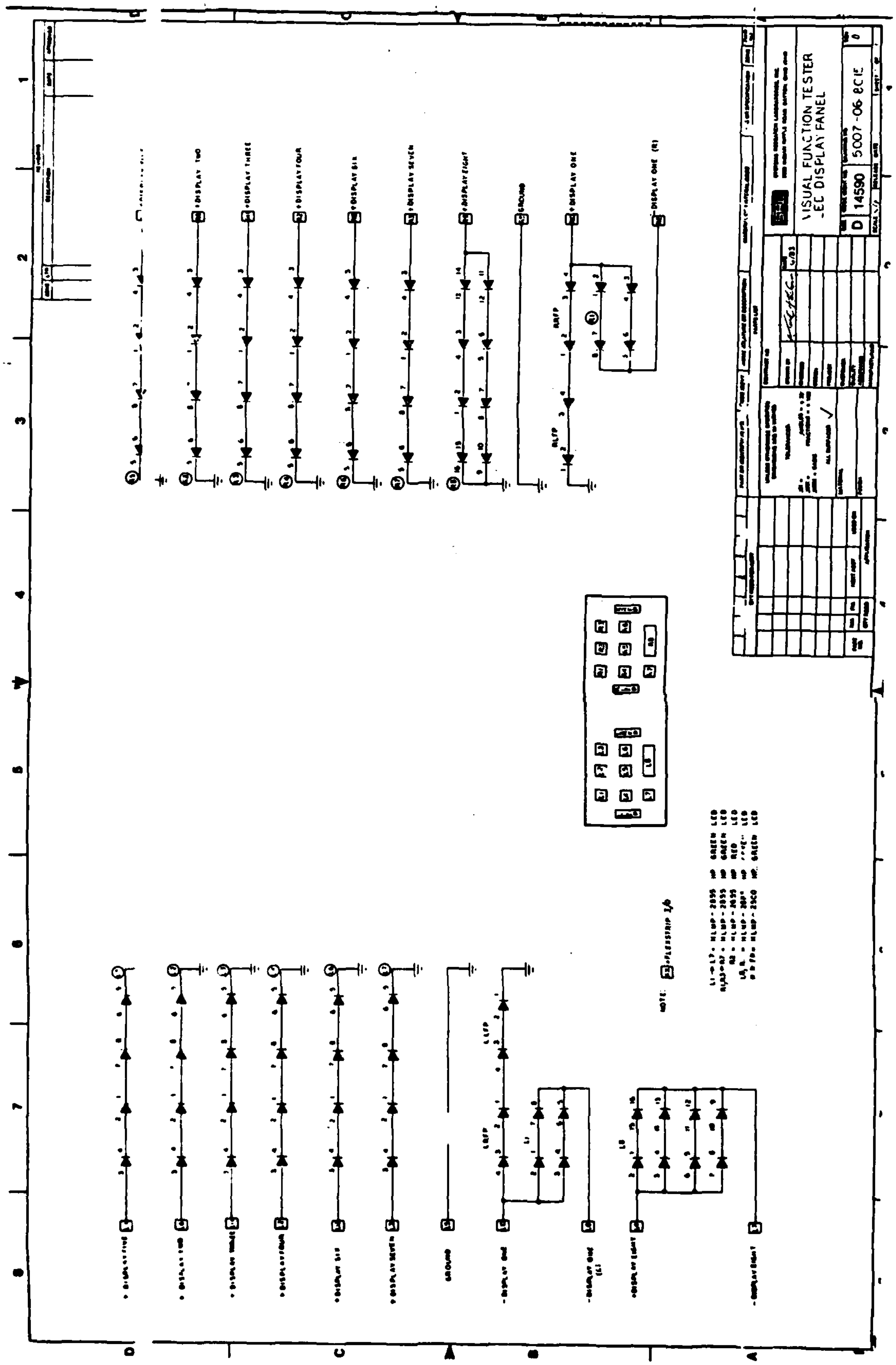
APPENDIX C

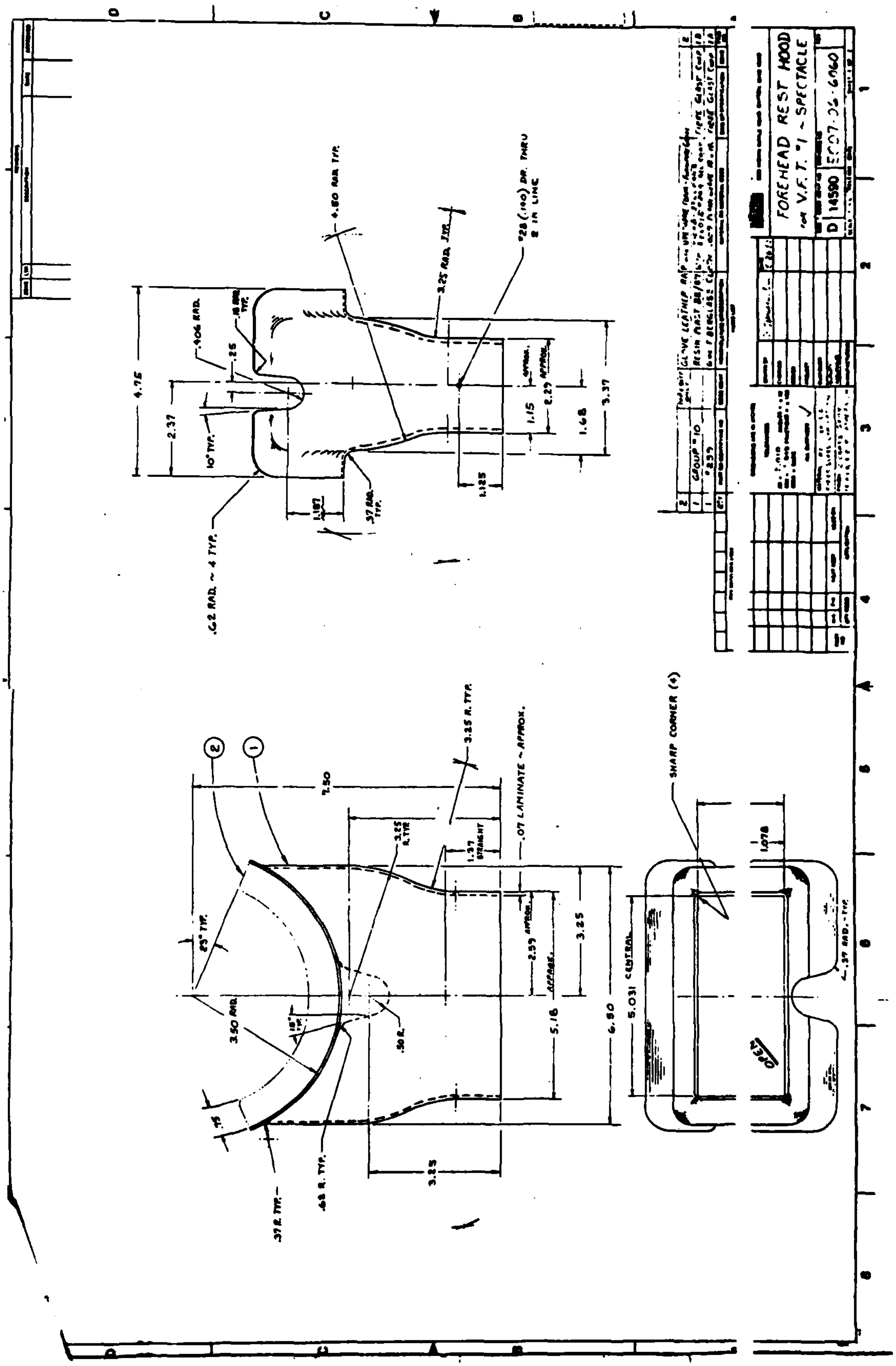
Schematic Diagrams


VISUAL FUNCTION TESTER
D
14590


VISUAL FUNCTION TESTER
D 14590 5007-06-8017
HP5082-7433 DISPLAY
BSI RESISTOR NETWORK
ENABLE READOUT (PG 2)
NOTE • = SIGNAL SOURCE
○ = SIGNAL DESTINATION


CLOCK
12-BIT COUNTER "A"
÷ 10
÷ 1000
1KHZ
RATE COUNTER
12-BIT COUNTER "B"
GATING & LIMIT LOGIC
CLOCK 2
UP
DOWN
FREQUENCY DISPLAY COUNTER/DRIVERS
FREQUENCY DISPLAY
READOUT ENABLE OR FLASH
FLASH & FLICKER LED DISPLAY DRIVER
ENABLE FLICKER LOGIC
ENABLE DIODES
ENABLE FLASH
DIRECT PWR TO STEADY LED DISPLAYS
ROTARY FUNCTION SELECT SWITCH
FOCAL POINT LEDS (4)
VISUAL FUNCTION TESTER
D
14580
5007-06-8009
0


VISUAL FUNCTION TESTER
-EC DISPLAY PANEL
D
14590



FOREHEAD REST HOOD
SHARP CORNER (4)
.07 LAMINATE ~ APPROX.

APPENDIX D

Forehead Rest Materials List

6 oz. Figerglass Cloth (Untreated) 5 Laminations

Plast 88/87 Epoxy Laminating Resin & Catalyst

Syloid 244 Silica Filler

Graphite Composite Ribbon 1 1/2" Wide

Tuf-Fil Polyester Filler & Catalyst (Freeman Co.)

Flat Black Lacquer 37038 (595 A) -- Illinois Bronze Co.

Platinum Gray Lacquer Primer -- New York Bronze Co.

DFL-17 Lacquer Putty Filler -- Ditzler Paint Co.

Urethane Foam Furniture Grade Flexible

Tandy Garment Cabretta Leather 9275

Weldwood Plus-10 Water Base Contact Cement

APPENDIX E

Visual Function Tester Model 1
Instructions

Hardware Description

The VFT-1 is a hand-held, battery-operated device which generates several visual test stimuli. All of the stimuli are located at optical infinity, so the user should always wear whatever prescription lenses are indicated for that distance. The stimuli are generated by using a series of electronically controlled flat LEDs to illuminate a precision target array. Each segment of the array tests a different visual function. The eyepieces are surrounded by a faceplate which both controls the eye-lens distance and helps shield the eyes and target from extraneous light.

Test displays are controlled by three pushbutton switches and one rotary switch located on the instrument. The rotary switch on the right side is numbered 0 to 9. 0 is the OFF position, 9 is unused. All other numbers indicate the number of the test being administered. The tests should be taken in sequence. The pushbutton switches on the top of the devices are labelled "UP", "DOWN" and "FREQ (Hz)". Their usage will be explained later. There are two displays on the top surface of the device. One, a green LED indicates Power On. The other is a digital readout which will display a number representing frequency in Hertz.

The batteries are contained in a small battery box at the back of the device. If necessary, they may be accessed by loosening the two button screws on the small top plate with a standard flat screwdriver. These screws will not back out of the cover, so they won't get lost. Also, the cover is attached to the main body of the VFT-1 with a cable so it won't drift away. Please be sure to turn the device OFF when not in use.

How to Record the Results

The tests should be taken as a series, in one "sitting" if possible. If you are interrupted for more than a few minutes, please restart from test #1.

To determine the effect of time in orbit on these visual parameters, please retake the tests as indicated in your activity schedule. If you think your distance vision is changing, and want to test yourself at irregular intervals, please record the data for these tests as well. We would like a couple of runs to be made at various times after landing to check on your eyes' recovery if anything changed while in space.

During all of the tests, verbally record your data by using the SONY BM-550 reserved microcassette tape recorder. We suggest you leave the recorder ON during the entire test. Please take care not to mix up the tapes or erase old data if the recorder is shared with another experiment.

We suggest recording the time, your name, and whether you underwent any environmental changes before this session. Since some of the tests are influenced by your retinal adaptation state, please don't look at bright lights for about a half hour before the test series. If you did, please tell us about it!

How to Self-Administer the Tests

TEST 1, CRITICAL FUSION FREQUENCY

1. Turn the rotary test selector dial to position #1.

2. Locate the UP and DOWN switches, and place one finger of each hand on them.

3. Hold the VFT-1 up to your eyes, and gently press your face into the headrest.

4. You should see a bright greenish disc in the upper left corner of your field of view. You should also see two small lights, one each on the far right and left of your field of view. If you don't, check the rotary switch position and the batteries.

5. The disc should appear to be flickering or blinking. While looking at the center of the disc, press the UP button until the flicker just disappears. The UP button may be held down constantly or pressed intermittently until the flicker just disappears.

6. Remove the device from your eyes, look at the numerical display, and press the FREQ (Hz) button. The display will light up, and stabilize within 2 or 3 seconds. Record the number on the display. Release the FREQ (Hz) button.

7. Press the DOWN button for about five seconds to reset the frequency generator.

8. Repeat steps 3 - 7 for a total of 5 trials.

9. Now look directly at the small light in the lower right corner of your field of view. The blinking light should be in the upper left area of your field of view. Do NOT look directly at the blinking light.

10. The large disc should appear to be flickering or blinking. Press the UP button until the flicker just disappears. The UP button may be held down constantly or pressed intermittently until the flicker just disappears.

11. Remove the device from your eyes, look at the numerical display, and press the FREQ (Hz) button. The display will light up, and stabilize within 2 or 3 seconds. Record the number on the display. Release the FREQ (Hz) button.

12. Press the DOWN button for about five seconds to reset the frequency generator.

13. Repeat steps 9 - 12 for five more trials.

TEST 2, STEREOPSIS

1. Turn the rotary switch to position #2.

2. You should see a series of dots, arranged in groups of four. Each dot is identified by both a letter (at the top of the target) and a number (on the left side of the target).

3. Your task is to start in the upper left corner of the test patch, and look at each group of dots from left to right. Call out the letter and number of the dot that appears to be closest to you in each group of four.

4. If no dots appear closer, describe the target in the upper left corner of the test patch ... is it a left slash (\), a right slash (/) or an "X"?

TEST 3, RESOLUTION ACUITY

1. Rotate the switch to position #3.

2. Look into the device. You should see a series of Es, and a skinny fan-like figure.

3. Starting at the top, and reading from left to right, record the line number and the orientation of each E in the line. The Es are either pointing UP, DOWN, RIGHT or LEFT. If you can't distinguish the position, say so. Read as far as you can go. Make your best guess if things look doubtful. Try to read all eight lines.

4. Now look to the right of the Es. You should see a group of nearly vertical lines in a fan-like arrangement. There are a series of numbers printed on the left side of the fan, and some horizontal hash marks associated with the numbers. Not all of the hash marks are numbered. Take a look at them so you recognize how they are interpolated.

5. Now look at the fan. The lines may be clear and separate at the top, but might run together at the bottom. Read out the number associated with the level at which the lines blur or run together. If they stay clear all the way to the bottom, say so.

TEST 4, RESOLUTION ACUITY (Repeat of test #3, different targets)

1. Rotate the switch to position #4.

2. Look into the device. You should see a series of Es, and a skinny fan-like figure.

3. Starting at the top, and reading from left to right, record the line number and the orientation of each E in the line. The Es are either pointing UP, DOWN, RIGHT or LEFT. If you can't distinguish the position, say so. Read as far as you can go. Make your best guess if things look doubtful.

4. Now look to the right of the Es. You should see a group of nearly vertical lines in a fan-like arrangement. There are a series of numbers printed on the left side of the fan, and some horizontal hash marks associated with the numbers. Not all of the hash marks are numbered. Take a look at them so you recognize how they are interpolated.

5. Now look at the fan. The lines may be clear and separate at the top, but might run together at the bottom. Read out the number associated with the level at which the lines blur or run together. If they stay clear all the way to the bottom, say so.

TEST 5, TORSIONAL PHORIA

1. Rotate the switch to position #5.

2. You should see a series of concentric circles, with an arrow pointing upward to some numbers and hash marks.

3. Record to which number the arrow points. Examples: If the arrow points directly at the #4 hashmark, record "4.0". If the arrow points half way between 4 and 5, record "4.5".

TEST 6, RESOLUTION ACUITY (Repeat of tests #3 & #4, different targets)

1. Rotate the switch to position #6.

2. Look into the device. You should see a series of Es, and a skinny fan-like figure.

3. Starting at the top, and reading from left to right, record the line number and the orientation of each E in the line. The Es are either pointing UP, DOWN, RIGHT or LEFT. If you can't distinguish the position, say so. Read as far as you can go. Make your best guess if things look doubtful.

4. Now look to the right of the Es. You should see a group of nearly vertical lines in a fan-like arrangement. There are a series of numbers printed on the left side of the fan, and some horizontal hash marks associated with the numbers. Not all of the hash marks are numbered. Take a look at them so you recognize how they are interpolated.

5. Now look at the fan. The lines may be clear and separate at the top, but might run together at the bottom. Read out the number associated with the level at which the lines blur or run together. If they stay clear all the way to the bottom, say so.

TEST 7, EYE DOMINANCE

1. Rotate the switch to position #7.

2. Look into the device. You should see a series of diagonal black lines in a red/green/yellow background. You will note that the red light and its associated lines are seen by your right eye, and the green light and its associated lines are seen by your left eye. Keep both eyes open!

3. The appearance of the target may change. Sometimes it may look mostly green (or mostly \\\\), and sometimes it might look mostly red (or mostly ////). It may be yellow with both sets of diagonals approximately equally visible. We want to find out how the target appears over a short period of time.

4. While keeping both eyes open, continuously call out which diagonal appears to occupy most of the target area. Example: Right...Right...Left...Right...Both...Right...Left... etc. Do not call out the color.

4. Keep this up for about 30 seconds.

TEST 8, LATERAL PHORIAS

1. Rotate the switch to position #8.

2. Locate the FREQ (Hz) button on the top of the device. Place one finger on it.

3. Look into the device. You should see a rectangular grid pattern with letters along the top and numbers along the left side.

4. Look at the center of the pattern, and <u>keep the lines as clear as you can.</u> Press <u>and release</u> the FREQ (Hz) button. <u>You should see a small dot appear for a short time</u> in or near one of the grid squares. If you missed it, press and release the FREQ (Hz) button again. Do not repeatedly flash it.

5. Record the letter and number of the grid square in which the bright dot appeared.

6. Repeat steps 3 - 5 for a total of five trials.

THATS IT! We sincerely appreciate your interest and cooperation!

Now please turn the switch back to position 0 to turn the device OFF. Also, stop the tape recorder. Please do not use the tape cassette for other purposes, so our data isn't erased.

Summary of Instructions

VFT-1 Tests.
Verbally record all data into tape recorder.

Switch Pos'n		ACTIVITY
1	A.	Look at center of blinking disk
	B.	Press UP until flicker stops
	C.	Look at FREQ Hz display
	D.	Press FREQ button
	E.	Record number displayed
	F.	Release FREQ button
	G.	Press DOWN button about 5 sec
	H.	Repeat steps A-F for a total of 5 trials
	I.	Look at lower right (nonblinking) dot.
	J.	Repeat steps B-F for a total of 5 trials
2	A.	State coordinates of closest dot in each group of four.
	B.	If no dots appear closer, describe target in upper left corner
3	A.	State direction of E in each row Read as far as you can
	B.	State largest number on resolution fan corresponding to lowest area you can resolve
4		(Same as test #3)
5		Record pointer reading. If it varies, describe the range
6		(Same as test #3)
7		Continuously call out direction of diagonals (\\\ is left, /// is right) of lines for approx 30 seconds
8	A.	Keep grid pattern clear
	B.	Press & Release FREQ button
	C.	Record coordinates of dot
	E.	Repeat steps A-C five times

Return rotary switch to position 0

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